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THE DISPERSED CUTICULAR FLORAS OF SOUTH AUSTRALIAN TERTIARY COALFIELDS, PART 1: SEDAN

by A. J. ROWETT*

Summary

ROWETT, A. I. (1991) The dispersed cuticular floras of South Australian Tertiary Coalfields, Part 1: Sedan. *Trans. R. Soc. S. Aust.* 115(1), 21-36, 31 May, 1991.

Dispersed cuticles were recovered from the three seams of the Sedan Coalfield and sixty-two parataxa have been identified. The floras of the two younger lignite seams are distinct from the underlying lignitic clay. The lignites are dominated by Proteaceae cuticle types with one cuticle type, identified as the cuticle of *Banksieaephyllum laeve*, i.e. *Banksieaephyllum* aff. *B. laeve* in abundance. The older lignite seam is distinguished by a large monospecific Myrtaceae component and a cuticle type identified as aff. *Agathis* (Araucariaceae). Other families represented in both seams include the Casuarinaceae, Elaeocarpaceae, Myrtaceae and Podocarpaceae. The flora of the under-lying lignitic clay is dominated by Lauraceae cuticle types.

The presence of *Banksieaephyllum* aff. *B. laeve* in the Sedan lignites suggests either an Oligocene-Miocene age for the lithotype or a longer stratigraphic range (extended lower limit) for the leaf-fossil.

KEY WORDS: Palaeobotany, Tertiary, Eocene, dispersed cuticles, Sedan, South Australia

Introduction

There are numerous coalfields found throughout South Australia ranging in age from Permian to Tertiary. The Tertiary deposits represent large resources of low-rank coal (lignite) of Middle to Late Eocene age that are distributed throughout sedimentary basins in the southern part of the State (S.A.D.M.E. 1987). These deposits include the Lochiel, Clinton, Beaufort, Bowmans and Whitwarta deposits of the Northern St Vincent Basin, Kingston in the south-east and the Anna and Sedan deposits on the edge of the Murray Basin. Three of these localities, Sedan, Lochiel and Kingston, are the subject of this study.

Previous dispersed cuticle investigations, the majority of which have been undertaken in the northern hemisphere (e.g. Peters 1963; Schneider 1969; Kovach & Dilcher 1984; Rowett 1986[1]) have revealed that lignites generally contain an abundance of cuticle fragments which can be assigned to either natural or form taxa. These data may subsequently provide information about the source vegetation associated with the formation of the specific lithotype as well as the past environment and climate. Such information is currently being used by the author in the correlation and dating of coal deposits.

The Sedan coalfield is located 75 km northeast of Adelaide (34° 34′, 139° 18′) on the margin of the Murray Basin, between the Mount Lofty Ranges and the River Murray (Fig. 1). Exploration in the vicinity of the nearby Anna deposit dates back to the 1920's but it was not until 1979 that the Sedan lignite was discovered. The deposit lies in a north-trending trough 5 km wide and 13 km long and comprises two main lignite seams. The upper seam, which is the most economically viable, is continuous and up to 8 m thick. The lower seam is lenticular and averages 5 m in thickness (S.A.D.M.E. 1987). Tertiary foraminiferal biostratigraphy (McGowran 1989) and a preliminary palynological analysis (N.F. Alley, S.A.D.M.E. pers. comm.) have dated the lignites as Late Eocene-Oligocene.

Materials and Methods

Drill core samples from both seams and the underlying lignitic clay taken from Sedan core CSR CO74B (7.5 cm diameter), housed in the S.A.D.M.E. core library are used in this investigation. Examination of these samples revealed considerable amounts of heavily carbonised dispersed cuticle and wood fragments. Cuticle fragments were extracted from 100g of matrix by modifying the maceration technique outlined by Christophel *et al.* (1987) to include an additional preliminary step whereby the crushed sample is placed in warm Schulze solution for approximately four hours prior to a dilute (50%) hydrogen peroxide solution step. The use of an additional oxidizing step assures the removal of any organic material from the cuticle and makes possible more accurate identifications and descriptions of cuticle types. The cuticle fragments were collected by passing the maceral through a

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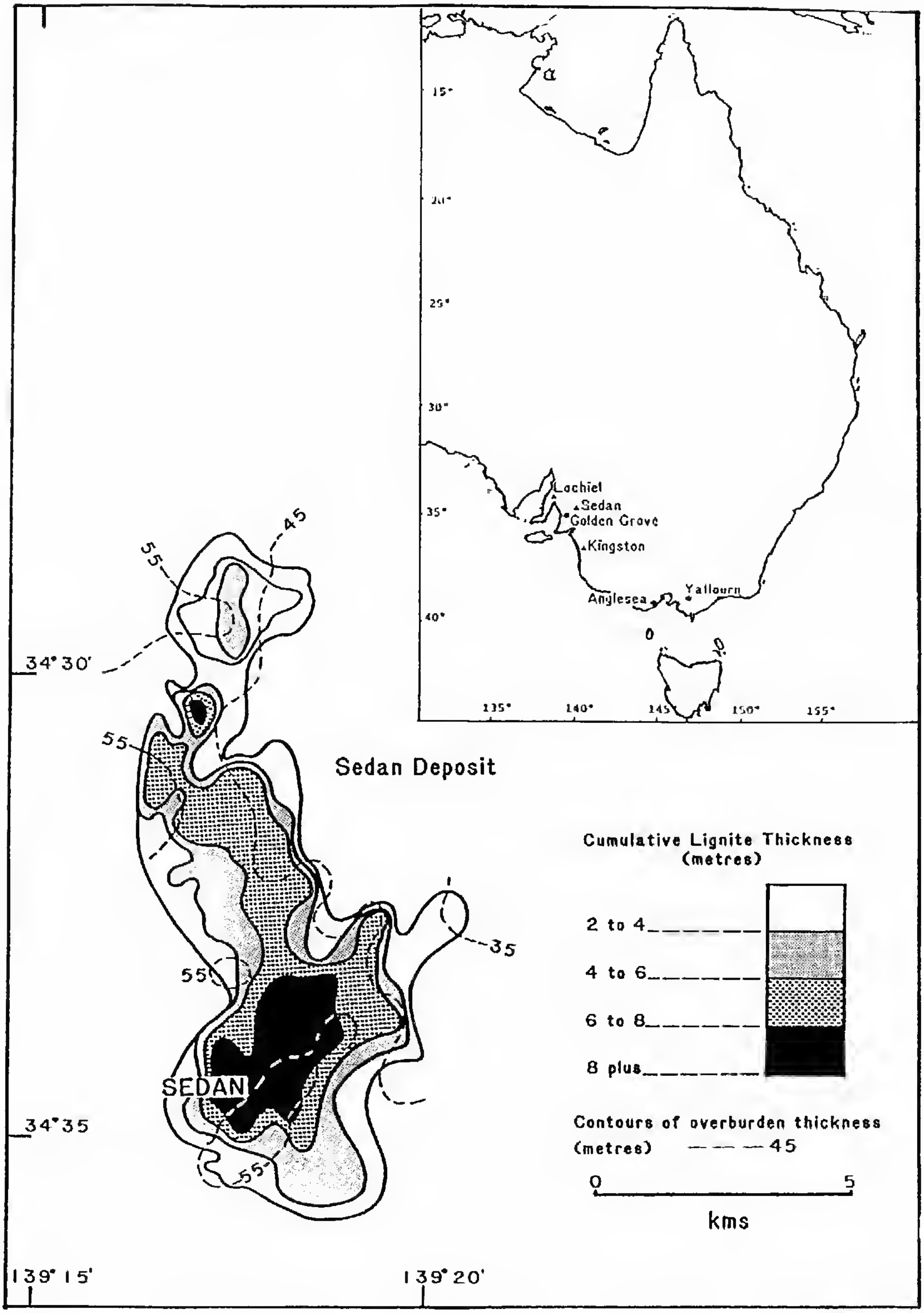
[1]Rowett, A. I. (1986) Megafossil and Microfossil Floras of the Curlew Foundation, Queensland. Ph.D. thesis, Botany Dept., University of Adelaide. Unpubl.



Lochiel
Sedan
Golden Grove
Kingston
Anglesea
Yallourn
Sedan Deposit
Cumulative Lignite Thickness (metres)
2 to 4
4 to 6
6 to 8
8 plus
Contours of overburden thickness (metres) 45
0 5
kms
SEDAN
34°30'
34°35
139°15'
139°20'

single fine pore sieve (150 μm diameter pore). The use of a multiple sieve series was considered unnecessary because of the small range in fragment size; none of the cuticles were greater than 2 mm^2. Examination of the cuticles revealed that no single cuticle paratrxon was size specific.

Only cuticle types (parataxa) that displayed stomates were considered in the overall analysis as the stomatal features are often diagnostic of a particular plant family, thereby greatly improving the chances of determining the modern affinities of fossil cuticles.

Five replicate samples of 200 cuticle fragments each (Rowett & Christophel 1990) were obtained from core material recovered from three depths, 54.8 m (upper seam), 67.5 m (lower seam) and 75.3 m (lignitic clay). The frequency data presented for both individual parataxa and modern families (i.e. Table 1) is a percentage calculated from the total of the five replicates of each lithotype.

The Dispersed Cuticle Flora

The three samples that contribute to the Sedan cuticle flora are separated by substantial intervals (approx. 10 m) of barren sediment (K. Wigglesworth, S.A.D.M.E. pers. comm.).

Lignitic Clay: The flora of the basal lignitic clay is dominated by the Lauraceae which forms 83.0% of the total cuticle sample (Table 1). This component is particularly diverse, containing 11 parataxa, of which the most frequent are parataxa No. AA 006 (30% of total sample; Figs 4 & 5) and No. S5 005 (19% of total sample; Figs 6 & 7). A number of these Lauraceae parataxa show possible affinities to the extant genera *Endiandra* and *Cryptocarya*. In *Endiandra* the epidermal cells are angular in appearance with irregularly thickened anticlinal walls, stomates are generally elongate with narrow but prominent cuticular scales (eg. No. AA 007, Fig. 2). These scales lie between the sunken guard cells and the overlying subsidiary cells. *Cryptocarya* is generally characterised by epidermal cells with smooth anticlinal walls of uniform thickness. Stomates are generally rounded with prominent reniform cuticular scales. These scales are dark-staining and give a butterfly-like appearance to the stomata (No. AG 005, Fig. 3).

The Myrtaceae component (3.1%) is represented in the flora by the cuticle types No. LC 011 (Figs 8 & 9) and No. S5 004 (Figs 11 & 12), with the latter being the most abundant. The most distinctive cuticular feature of the Myrtaceae is the oil gland lid cell. These cells, which may occur on either/or both cuticular surfaces, are generally isodiametric, divided by a curved to sinuous sinus, surrounded by a number of concentric circles of radially arranged epidermal cells and display some degree of cuticular thickening.

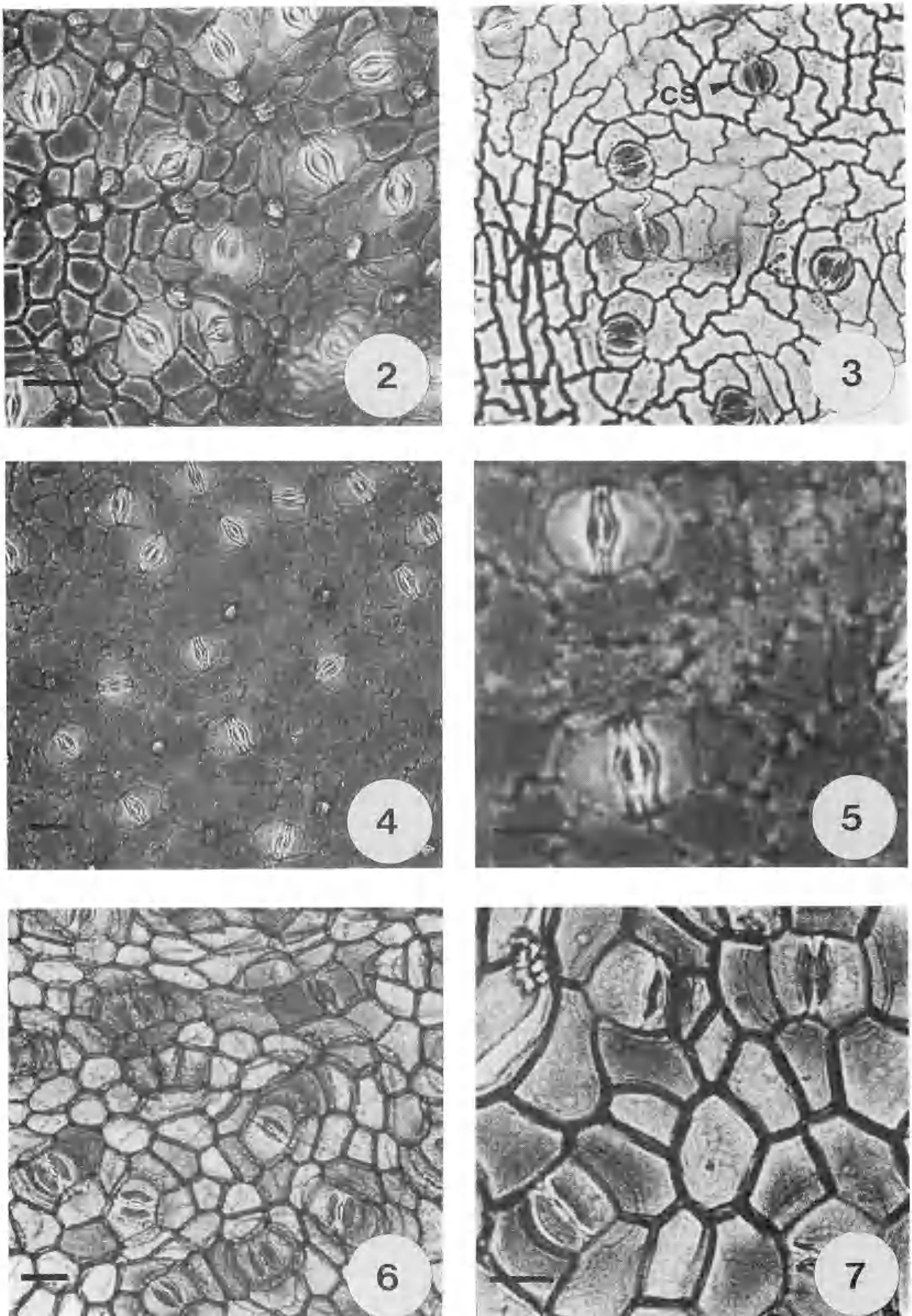
Falcatifolium aff. *F. australis* Greenwood (Figs 13 & 14) is the principal contributor to the small Podocarpaceae component (0.8%). The parataxon is suggested as having an affinity to *Falcatifolium australis* on the basis of the circular appearance of the stomata, a feature considered to be distinctive by Greenwood (1987), who first identified the species from the Upper Middle Eocene fossil flora of the Anglesea locality. A very small Proteaceae component (0.2%) is also present in this lithotype.

Lower Lignite Seam: The cuticle flora of the lower lignite seam is significantly different from that of the underlying clay. The most obvious differences include the replacement of the Lauraceae as the principal floristic component by the Proteaceae, the

TABLE 1. *The cuticle frequencies (%) of extant plant families represented in the three Sedan lithological units. The families represented are Podocarpaceae (POD), Araucariaceae (ARAUC), Myrtaceae (MYRT), Elaeocarpaceae (ELAEO), Proteaceae (PROT), Lauraceae (LAUR), Casuarinaceae (CAS). The OTHERS category represents all other cuticle parataxa whose modern family affinities are unknown.*

LOCALITY	POD	ARAUC	MYRT	ELAEO	PROT	LAUR	CAS	OTHERS
SEDAN 54.68 m	2.1	–	0.4	1.3	93.0	0.7	0.1	2.2
SEDAN 67.50 m	3.0	2.0	14.5	9.0	40.4	0.5	0.5	29.6
SEDAN 75.30 m	0.8	–	3.1	0.4	0.2	83.0	–	12.5

Fig. 1. Map showing the extent and thickness of lignite in the Sedan deposit. The town of Sedan is situated above the deposit. Inset: Map of eastern Australia showing the location of the Sedan, Lochiel and Kingston coal localities relative to the Tertiary Megafossil localities of Golden Grove (Eocene), Anglesea (Eocene) and Yallourn (Oligocene).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presence of an Araucariaceae and Casuarinaceae component and increased abundances in the Myrtaceae and Podocarpaceae components. The Elaeocarpaceae is present for the first time.

As stated above, the flora is dominated by the Proteaceae with parataxon No. S1 001 the major contributor. Parataxon No. S1 001 (Figs 17 & 18) has a very distinctive cuticle with slightly raised brachyparacytic stomates, small simple hairs associated with a single epidermal cell which are common over the stomatiferous surface and large multicellular hair bases. These features are characteristic of the cuticle of the fossil leaf genus, *Banksieaephyllum* (Proteaceae). The genus was first used to describe six fossil leaf species, i.e. *B. angustum, B. acuminatum, B. laeve, B. obovatum, B. pinnatum* and *B. fastigatum*, with affinities to the modern genera *Banksia* and *Dryandra* (Cookson & Duigan 1950). These leaves were recovered from the Oligocene aged brown coal seam at Yallourn, Victoria. At present eleven species of *Banksieaephyllum* are recognised. These species have all been recovered from southeastern Australian localities ranging from Early Eocene to Early Miocene in age and include, the Middle Eocene Maslin Bay deposit (Blackburn 1981; Hill & Christophel 1988), Early Eocene Deans Marsh, late Middle Eocene Anglesea, Middle Eocene Golden Grove, Late Eocene-Oligocene Cethana, Middle-Late Eocene Loch Aber, Oligocene Pioneer, Oligocene-Early Miocene Loy Yang (Hill & Christophel 1988) and Miocene Morwell (Blackburn 1985[2]). Of the eleven described species, cuticle of *Banksieaephyllum laeve* from the Yallourn Oligocene brown coal flora (Cookson & Duigan 1950) and Miocene flora of the Morwell seam at Morwell most closely resembles parataxon No. S1 001.

The increased Myrtaceae component (14.5%) is represented in the flora by a single parataxon No. S3 001 (Figs 15 & 16). This parataxon only occurs in this lithotype and is distinct from the other Sedan Myrtaceae by the robust nature of the generally larger cuticular features.

The Casuarinaceae component, although a minor contributor to the overall flora, is important in that the presence of the parataxon No. DM 007 (Figs 19 & 20), identified as *Gymnostoma* is the first dispersed cuticle record of the occurrence of this well known Tertiary genus outside of eastern Australia. The cuticle of this parataxon is very distinctive with stomates oriented perpendicular to the longitudinal axis of the epidermal cells. The stomates may have one or two lateral subsidiary cells. The genus was first reported from the Anglesea deposit by Christophel (1980) as a megafossil of the Casuarinaceae, Division Gymnostomae, and has since been discovered in the floras of a number of Tertiary plant fossil localities which range from Middle Eocene to Miocene and include Deans Marsh (Middle Eocene), the Curlew Formation (Middle Eocene), Moranbah (Middle Eocene; Scriven & Christophel 1990), and Yallourn and Morwell open cut mines (Oligocene-Miocene, Blackburn 1985). *Gymnostoma* cone impressions have also been identified in the silcretes of the Eyre Formation (Late Palaeocene-Eocene), Willilinchina Sandstones (Eocene) and Etadunna Formation (Oligo-Miocene) (Greenwood *et al.*[3]).

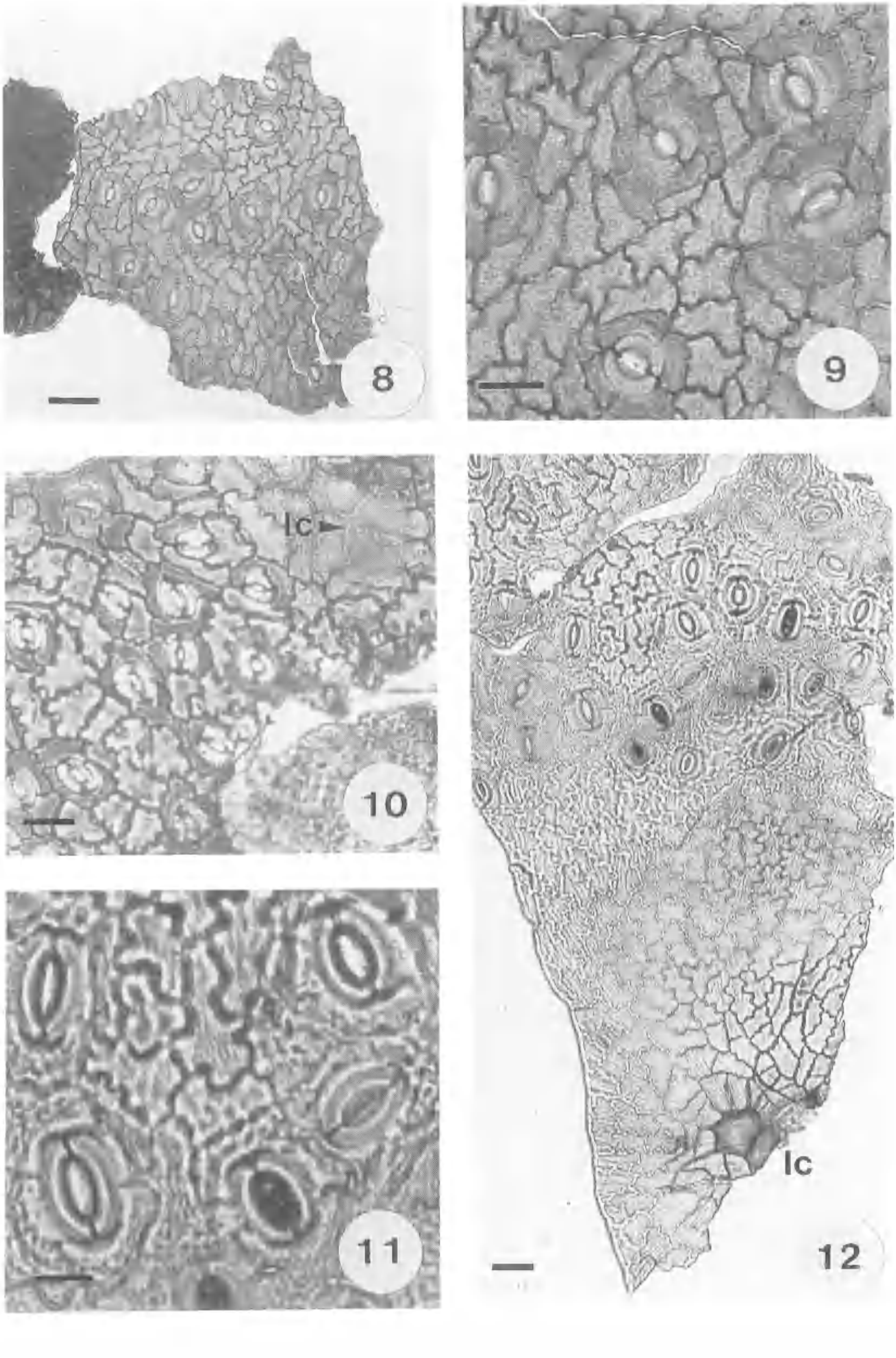
Parataxon No. AWF 001 (Figs 21 & 22), the sole representative of the Araucariaceae component is only found in this lithotype and may therefore prove to be a useful local stratigraphic indicator. This cuticle type is tentatively assigned to *Agathis* on the basis of the oblique orientation of stomata and the curved to rounded nature of the epidermal cells.

The large Elaeocarpaceae component (9.5%) is represented in this lithotype by two cuticle types Nos. S3 004 (Figs 23 & 24) and S3 005 (Fig. 25), the former being the major contributor with 8.0% of the cuticle sample. Both parataxa occur for the first time in the Sedan deposit. Features of the cuticle which are considered characteristic of the family are the presence of hydathodes (Blackburn 1985), staurocytic stomates and a prominent, narrow outer stomatal ledge which bears small polar extensions, termed an apiculate outer stomatal ledge by Wilkinson (1979).

[2]Blackburn, D. T. (1985) Palaeobotany of the Yallourn and Morwell coal seams. Palaeobotany Report No. 3, State Electricity Commission of Victoria. Unpubl.

[3]Greenwood, D. R., Callen, R., & Alley, N. F. (1990) Biostratigraphy of the Cainozoic Macroflora of the southern Eyre Basin in South Australia. Report, South Australian Department of Mines and Energy. Unpubl.

Figs 2–7. 2. Parataxon No. AA 007, aff. *Endiandra*, Lauraceae. The presence of prominent, narrow cuticular scales and angular epidermal cells are features associated with the extant genus. Scale = 20 μm. 3. Parataxon No. Ag 005, aff. *Cryptocarya*, Lauraceae. The presence of prominent reniform to crescent-shaped cuticular scales (i.e. cs, arrowed) which give the stomatal apparatus a butterfly-like appearance; stomata and undulate epidermal cells are features associated with the extant genus. Scale = 24 μm. 4. Parataxon No. AA 006, Lauraceae, showing stomatiferous surface. Note the sinuous nature of the epidermal cells and poral trichome bases. Scale = 20 μm. 5. Parataxon No. AA 006, Lauraceae, showing the paracytic stomatal arrangement and prominent cuticular scales. Scale = 12 μm. 6. Parataxon No. AA 008 aff. *Cryptocarya*, Lauraceae, showing stomatiferous surface. Note the smooth, uniformly thickened anticlinal walls of the epidermal cells. Scale = 20 μm. 7. Parataxon No. AA 008 aff. *Cryptocarya*, Lauraceae, showing paracytic stomatal arrangement and crescent-shaped to reniform cuticular scales. Scale = 20 μm.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Although showing an increased abundance (3.0%), with the introduction of parataxon No. LE 009 (Fig. 26), the Podocarpaceae component remains a minor contributor at this depth. Parataxon No. LE 009 is easily distinguished from *Falcatifolium* aff. *F. australis* by the strong buttressing of anticlinal walls of the epidermal cells.

Upper Lignite Seam: The upper seam flora, is the most diverse with 30 parataxa represented, the majority of which are recognised as having affinities with the families, Proteaceae, Elaeocarpaceae, Myrtaceae, Podocarpaceae, Lauraceae and Casuarinaceae. The Proteaceae dominates the flora (93.0%) with two parataxa, *Banksieaephyllum* aff. *B. laeve* and parataxon No. SI 003 (Figs 27 & 28), in particular abundance. The only other families of any significance in the flora are the Podocarpaceae and Elaeocarpaceae which record frequencies of 2.1% and 1.3%, respectively. The Podocarpaceae component shows an increased diversity in this seam with six parataxa represented. The parataxa which dominated the component of the other floras, i.e. *Falcatifolium* aff. *F. australis* and parataxon No. LE 009, are again the major contributors in this lithotype. The small Myrtaceae component is marked by the reappearance of parataxon No. LC 011.

Four different cuticle types comprise the Elaeocarpaceae component with parataxon No. ALL 011 the most abundant. Cuticles taken from mummified leaves ascribed by Christophel & Greenwood (1987) to *Sloanea/Elaeocarpus* from Golden Grove and leaf type "Serrate 1" described by Christophel *et al.* (1987) from Anglesea are identical to those identified as parataxon No. ALL 011 in the Sedan flora (Fig. 29).

Dispersed Cuticle Descriptions

The dispersed cuticle flora of the Sedan coalfield is represented by 62 cuticle parataxa but for the purpose of this paper only the principle cuticle parataxa, stratigraphically significant parataxa and those with known modern affinities are described here. Several of the parataxa have been previously identified by the author from other Eocene localities. These and many more are included in the NERDDC reference catalogue of Australian Eocene cuticle types. All parataxon numbers are preceded by an abbreviation of the type locality.

The terminology used in the description of the Sedan cuticle parataxa has been derived from that proposed by Stace (1965), Dilcher (1974) and Wilkinson (1980).

Cuticle Parataxon No. AA 007
FIG. 2

Only the stomatiferous surface was observed. Epidermal cells angular to rounded (type 1-2, Wilkinson 1979), becoming elongate over the veins. Cells 8-24 μm in length, 6-16 μm in width. Anticlinal wall irregularly thickened, smooth (uniform thickness) to slightly beaded. Periclinal wall irregularly thickened, smooth to finely granulate. Stomata randomly oriented, uniform distribution. Stomata 16-24 μm in length, 6-16 μm in width. Guard cells, sunken, cuticular thickening on poral wall. Cuticular scales (i.e. labelled CS2 on Fig. 1, Hill 1986), prominent, narrow. Stomatal Arrangement paracytic. Stomatal Index (S.I.) 11.4. Subsidiary cells cells 2. Anticlinal wall, thin, smooth, Periclinal wall thin, smooth.

Trichome bases common, uniform distribution, poral, 4-8 radially arranged surrounding cells, cuticular thickening around pore extending along radial wall of surrounding cells giving stellate appearance.

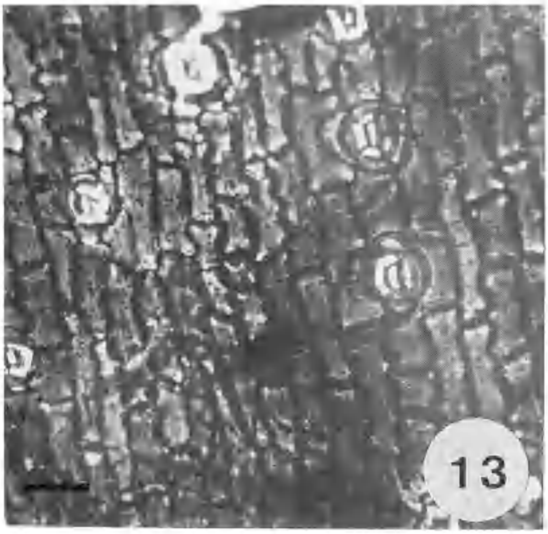
Affinity: The parataxon is assigned to the Lauraceae, with a probable affinity to the extant genus *Endiandra*. The modern Australian species of this genus are characterised by predominantly angular epidermal cells with irregularly thickened anticlinal walls, elongate stomates with prominent, though narrow cuticular scales.

Cuticle Parataxon No. AG 005
FIG. 3

Only the stomatiferous surface was observed. Epidermal cells undulate to sinuous (type 3-5), becoming elongate over the veins. Cells 20-40 μm in length, 12-20 μm in width. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, smooth to finely granulate (occasionally finely striate).

Stomata randomly oriented, uniform distribution. Stomata 16-24 μm in length, 12-20 μm in width. Guard cells, sunken, cuticular thickening on poral wall. Guard cell/subsidiary cell wall not always

Figs 8-12. 8. Parataxon No. LC 011. Myrtaceae. The dark-staining subsidiary cells and the sinuous nature of the epidermal cells characterise this parataxon. Identical in cuticular morphology to specimens from Lochiel. Scale = 20 μm. 9. Parataxon No. LC 011, Myrtaceae, showing staurocytic stomatal arrangement. Scale = 20 μm. 10. Specimen of Parataxon No. LC 011, Myrtaceae from Lochiel, note the same cuticular morphology as the Sedan specimens and the presence of an oil gland lid cell (i.e. lc, arrowed). Scale = 20 μm. 11. Parataxon No. S5 004, Myrtaceae, showing stomatal arrangement. Note the strongly striate periclinal wall of the epidermal cells. Scale = 10 μm. 12. Parataxon No. S5 004, Myrtaceae, showing a heavily cutinized oil gland lid cell (lc, arrowed). Scale = 20 μm.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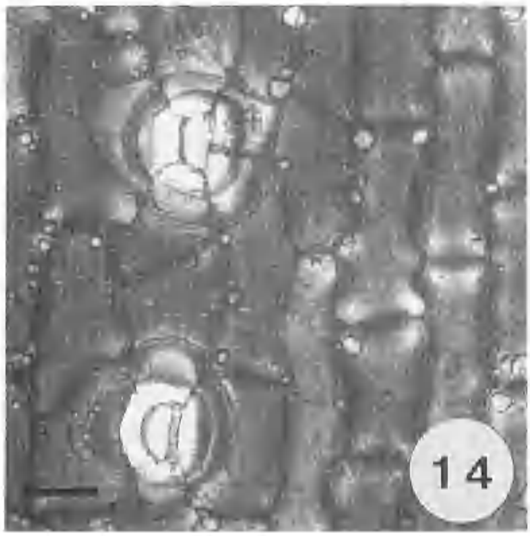
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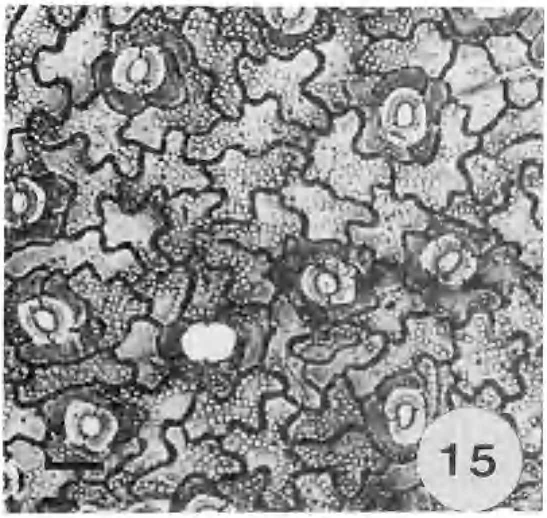
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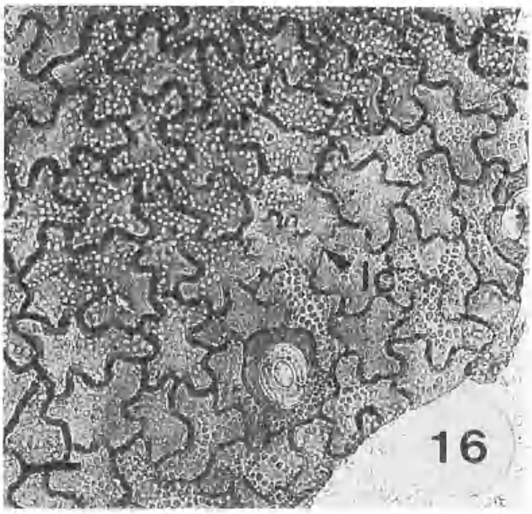
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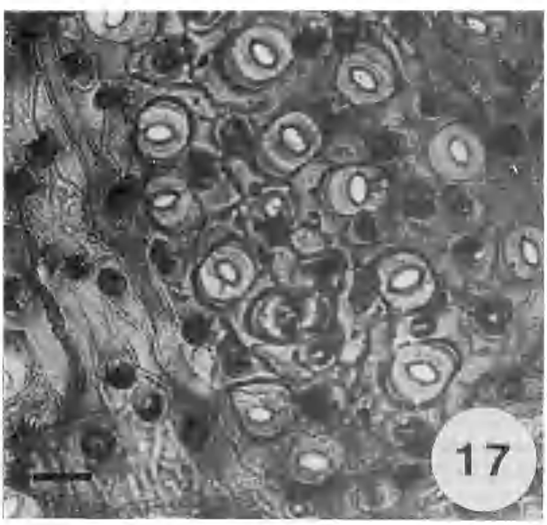
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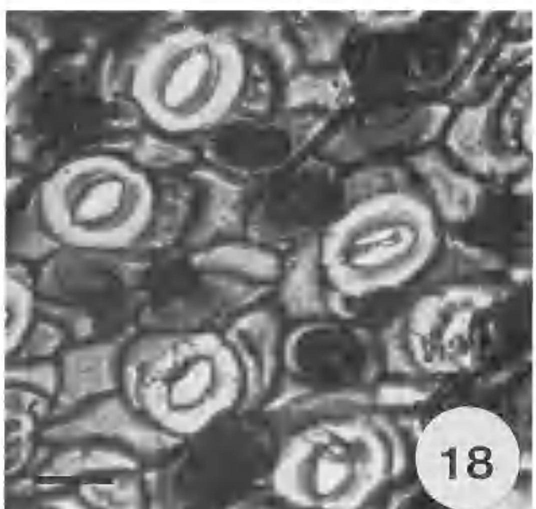
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evident (in which case the stomatal width dimension is taken as a measure across the two subsidiary cells, instead of the usual guard cell width). Cuticular scales, prominent, reniform to crescent-shaped, giving a butterfly-like appearance to the stomate. Stomatal Arrangement paracytic. S.I. 6.2. Subsidiary cells two. Anticlinal wall smooth, thicker than for epidermal cells and raised which produces a cuticular fold that encircles and partially overlies the stomate. Periclinal wall thin, smooth.

Trichome bases common, uniform distribution, poral, 4-8 radially arranged surrounding cells, cuticular thickening around pore.

Affinity: The cuticle parataxon is assigned to Lauraceae with a probable affinity to the extant genus *Cryptocarya*. The modern Australian species of this genus are characterised by epidermal cells with smooth anticlinal walls; shape is variable. Stomates are generally rounded with prominent reniform to crescent-shaped cuticular scales which gives a butterfly-like appearance to the stomatal apparatus.

Cuticle Parataxon No. AA 006
FIGS 4–5

Only the stomatiferous surface was observed. Epidermal cells rounded to sinuous (type 2–5), becoming elongate over the veins. Cells 12–36 μm in length, 8–20 μm in width. Anticlinal wall irregularly thickened, smooth to ridged (Dilcher; 1974). Periclinal wall irregularly thickened, smooth to granulate.

Stomata randomly oriented, uniform distribution. Stomata 16–20 μm in length, 8–10 μm in width. Guard cells, sunken, cuticular thickening on poral wall. Cuticular scales, prominent, narrow. S.I. 9.5. Stomatal Arrangement paracytic. Subsidiary cells 2. Anticlinal wall irregularly thickened, smooth to beaded. Periclinal wall irregularly thickened, smooth to granulate.

Trichome bases common, uniform distribution, poral, 5–6 radially arranged surrounding cells, cuticular thickening around pore.

Affinity: The cuticle is assigned to the Lauraceae due to the presence of paracytic stomates and inconspicuous, sunken guard cells.

Cuticle Parataxon No. S5 005
FIGS 6–7

Only the stomatiferous surface was observed. Epidermal cells angular, becoming elongate over the veins. Areoles are well-defined. Cells 16–32 m in length, 8–20 m in width. Anticlinal wall thin, smooth (occasionally buttressed). Periclinal wall irregularly thickened, smooth to granulate to striate. Stomata randomly oriented, uniform distribution. Stomata 18–24 m in length, 16–28 m in width. Guard cells, sunken. Guard cell/subsidiary cell wall absent (in which case the stomatal width dimension is taken as a measure across the two subsidiary cells, instead of the usual guard cell width). Cuticular scales, prominent, reniform to crescent-shaped. Stomatal Arrangement paracytic. S.I. 8.6. Subsidiary cells 2. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, smooth to granulate to finely striate. Striations generally perpendicular to the long axis of the stomate. Epidermal cells that immediately surround the stomate are occasionally dark-staining. Trichome bases are rare, only found over veins. Poral with 4–6 radially arranged surrounding cells. Bases are thickened around the pore.

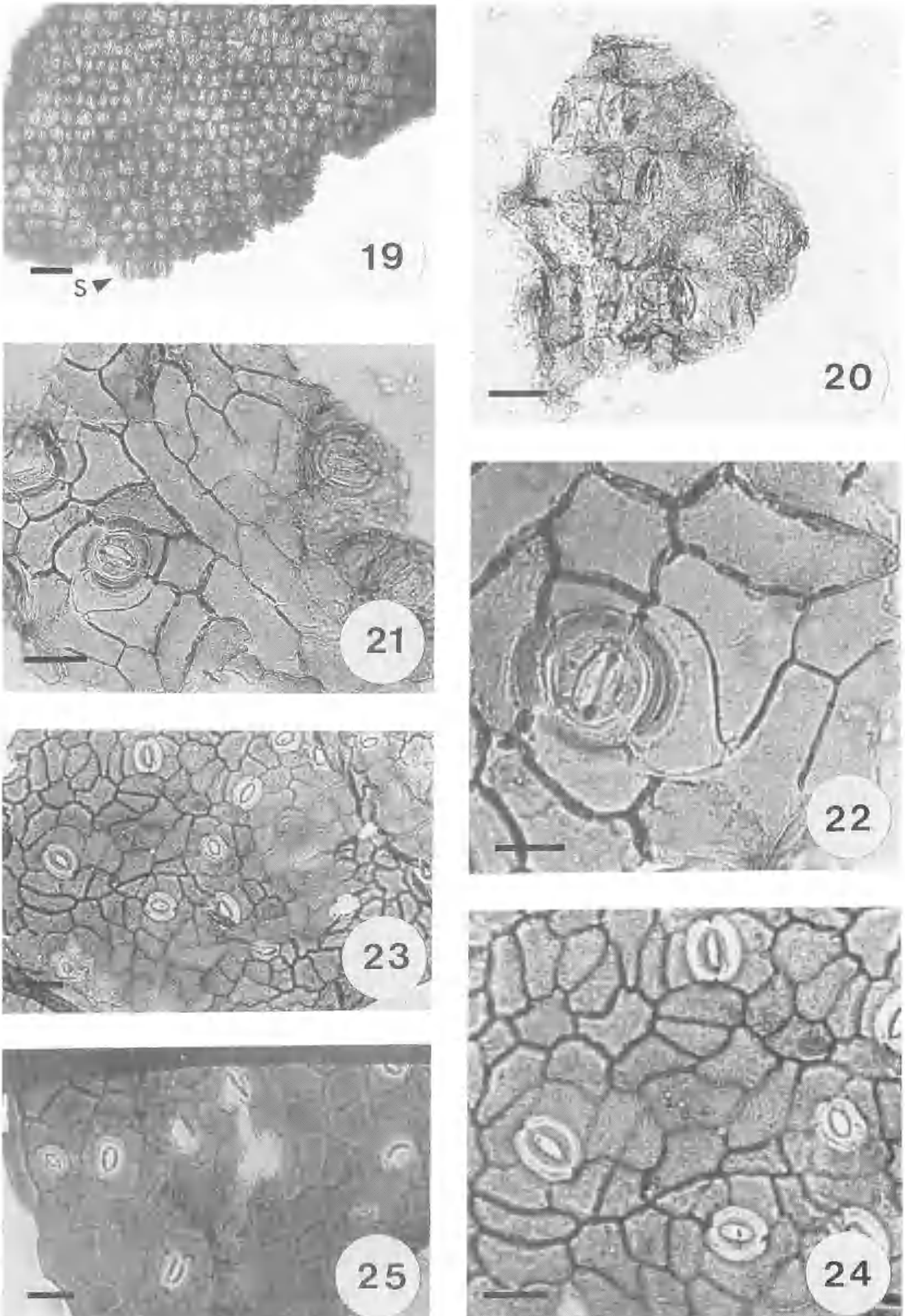
Affinity: The cuticle parataxon is assigned to the Lauraceae with a probable affinity to the extant genus *Cryptocarya* due to the presence of epidermal cells with predominantly smooth anticlinal walls and reniform to crescent-shaped cuticular scales.

Cuticle Parataxon No. LC 011
FIGS 8–9

Only the stomatiferous surface was observed. Epidermal cells undulate to sinuous (type 3–5), becoming elongate over the veins. Cells 16–32 m in length, 10–24 m in width. Anticlinal wall irregularly thickened, smooth to beaded to slightly buttressed. Periclinal wall thin, smooth.

Stomata randomly oriented, uniform distribution. Stomata 16–32 m in length, 16–24 m in width. Guard cells, sunken, T-shaped thickening and polar rods present. Outer stomatal ledge, prominent, narrow. Stomatal Arrangement staurocytic (to cyclocytic). S.I. 10.6. Subsidiary cells 3–6, darker staining. Anticlinal wall irregularly thickened,

Figs 13–18. 13. Parataxon No. ABD 001, *Falcatifolium* aff. *F. australis*, Podocarpaceae, showing arrangement of stomata in short uniseriate row. Scale = 32 μm. 14. Parataxon No. ABD 001, *Falcatifolium* aff. *F. australis*, Podocarpaceae. Note the shape of the subsidiary cells and the resultant circular appearance of stomata. Scale = 26 μm. 15. Parataxon No. S3 001, Myrtaceae, showing the stomatiferous surface. Note the dark-staining subsidiary cells. Scale = 30 μm. 16. Parataxon No. S3 001, Myrtaceae, showing an oil gland lid cell (arrowed). Note the sinuous nature of the lid cell sinus. Scale = 30 μm. 17. Parataxon No. S1 001, *Banksieaephyllum* aff. *B. laeve*, Proteaceae, showing the stomatiferous surface. Scale = 20 μm. 18. Parataxon No. S1 001, *Banksieaephyllum* aff. *B. laeve*, Proteaceae, showing the stomatal arrangement. Note the short, cylindrical papillae are present on most epidermal cells. The stomata appear slightly raised above the cuticle surface. Scale = 17 μm.



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smooth to beaded. Periclinal wall thin, smooth. *Affinity:* Myrtaceae. Although oil gland lid cells that are usually found on myrtaceous leaves were not observed on fragments recovered from this locality, the general cuticular morphology is very similar to that of specimens recovered from the Lochiel coalfield (Fig. 10) which are unequivocally Myrtaceae.

Cuticle Parataxon No. S5 004
FIGS 11–12

Only the stomatiferous surface was observed. Epidermal cells sinuous (type 4–6). Cells 12–36 μm in length, 10–28 μm in width. Anticlinal wall irregularly thickened, smooth to beaded to ridged. Periclinal wall striate.
Stomata randomly oriented, uniform distribution. Stomata 16–26 μm in length, 12–16 μm in width. Guard cells slightly sunken, T-shaped thickening and polar rods present. Outer stomatal ledge, prominent, narrow. Stomatal Arrangement staurocytic. Subsidiary cells 3–5 more undulate in outline. Anticlinal wall beaded, radial wall often absent or incomplete. Periclinal wall thin, striate. Oil gland lid cells common, prominent, constricted at sinus, sinus straight, dark-staining, thicker cuticle than found over epidermal cells, dimensions 32–44 μm in length, 12–24 μm in width. Lid cell surrounded by a number of circles of radial arranged modified epidermal cells. Striations radiate outwards from lid cell.
Affinity: The presence of oil gland lid cells and the general stomatal morphology which includes features like a well-defined, circular guard cell complex and a prominent stomatal ledge, indicate the cuticle is of the Myrtaceae.

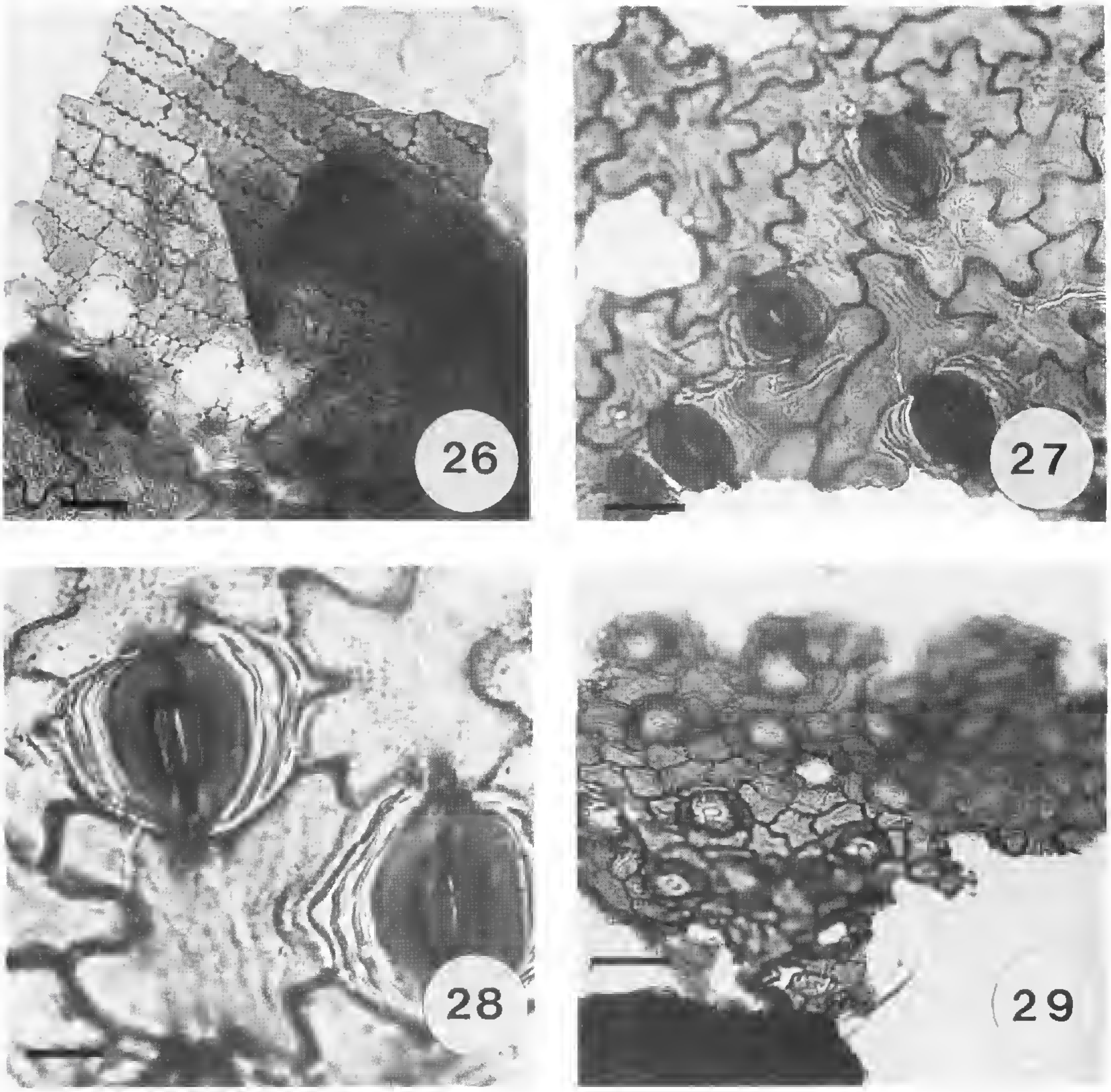
Cuticle Parataxon No. ABD 001
FIGS 13–14

Only the stomatiferous surface was observed. Epidermal cells angular (predominantly rectangular) arranged in longitudinal rows oriented parallel to the long axis of the leaf. Cells 32–68 μm in length, 20–64 μm in width. Anticlinal wall thin, smooth. Periclinal wall granulate.
Stomata in poorly defined uniseriate rows which suggests the specimen is of the adaxial surface of the leaf. The stomata are oriented parallel to the long axis of the leaf. Stomata 32–44 μm in length, 32–40 μm in width. Guard cells, sunken, poral thickening present. Outer stomatal ledge, prominent, thick, broad with polar extensions over radial anticlinal walls. Florin rings evident. Stomatal arrangement paratetracytic, circular in appearance. Subsidiary cells 4, crescent-shaped lateral cells larger than wedge-shaped polar cells. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, granulate to striate.
Affinity: The cuticle parataxon is assigned to *Falcatifolium* (Podocarpaceae), with a possible affinity to the fossil species *F. australis*. This species was described from the Anglesea deposit by Greenwood (1987) who noted the distinctive circular appearance of the stomata, a feature also exhibited by the Sedan specimens.

Cuticle Parataxon No. S1 001
FIGS 17–18

Hypostomatic. Adaxial epidermal cells angular becoming elongate over veins. Cells 20–36 μm in length, 12–28 μm in width. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, smooth to finely granulate. Trichome bases common, single to multicellular, up to 7 basal cells, heavily cutinized, trichome scar evident.
Cuticle thinner than on adaxial surface. Abaxial epidermal cells (angular to) rounded to undulate (type 3), becoming elongate over veins. Cells 16–40 μm in length, 8–16 μm in width. Anticlinal wall irregularly thickened, smooth to beaded. Periclinal wall irregularly thickened, smooth to papillate. Papillae present on most epidermal cells, short, cylindrical, truncate apex, up to 16 μm in length. Large papillae common, arise from multicellular bases (2-celled), basal cells heavily cutinized, cuticle of papillae also thick, up to 24 μm in length, dome-shaped. Stomata randomly oriented, uniform distribution. S.I. 15.5. Stomata 18–24 μm in length, 12–22 μm in width. Stomatal arrangement brachyparacytic. Guard cells slightly raised, show

Figs 19–25. 19. Parataxon No. DM 007, *Gymnostoma*, Casuarinaceae. The delicate nature of this cuticle makes recovery difficult and stomates are rarely preserved. Scale = 40 μm. 20. Parataxon No. DM 007, *Gymnostoma*, Casuarinaceae, a slightly better preserved fragment showing a segment of a number of stomatal rows. Note the perpendicular orientation of the stomata relative to the intermediate epidermal cells. Scale = 20 μm. 21. Parataxon No. AWF 001, aff. *Agathis*, Araucariaceae. Note the oblique orientation of the stomates and the prominent Florin rings associated with the stomates. Scale = 40 μm. 22. Parataxon No. AWF 001, aff. *Agathis*, Araucariaceae, showing the stomatal arrangement and the darker staining Florin ring which overlies the subsidiary cells. Scale = 20 μm. 23. Parataxon No. S3 004, Elaeocarpaceae, showing stomatiferous surface. Scale = 20 μm. 24. Parataxon No. S3 004, Elaeocarpaceae, showing the anomocytic and staurocytic stomatal arrangement. Note the apiculate outer stomatal ledge, i.e. ledge with small polar protrusions, on the guard cells. Scale = 20 μm. 25. Parataxon No. S3 005 Elaeocarpaceae, showing the stomatiferous surface, note the staurocytic stomatal arrangement. Scale = 20 μm.



Figs 26–29. 26. Parataxon No. LE 009, Podocarpaceae, showing distinctive buttress thickening of the epidermal cells. Scale = 40 μm. 27. Parataxon No. S1 003, Proteaceae, showing the stomatiferous surface. Note the broad, thick stomatal ledge and prominent T-shaped thickening on the guard cells. Scale = 40 μm. 28. Parataxon No. S1 003, Proteaceae, showing the brachyparacytic stomatal arrangement. Note the prominent striations on the subsidiary cells. Scale = 19 μm. 29. Parataxon No. ALL 011, aff. *Sloanea/Elaeocarpus*, Elaeocarpaceae. The thin guard cells are surrounded by, up to 6, dark staining subsidiary cells. Scale = 32 μm.

slight poral thickening. Subsidiary cells 2. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, smooth to finely granulate, slightly thicker cuticle, slightly darker staining. Glandular bodies present.

Affinity: The cuticle parataxon is assigned to the Proteaceae on the basis of a brachyparacytic stomatal and multicellular trichome base arrangement. The cuticular features are identical to those of the cuticle of the Yallourn open cut fossil *Banksieaephyllum laeve.* The Sedan cuticle type is therefore identified as *Banksieaephyllum* aff. *B. laeve.*

Cuticle Parataxon No. S3 001
FIGS 15–16

Only the stomatiferous surface was observed. Epidermal cells undulate (type 3–4). Cells 36–64 μm in length, 12–36 μm in width. Anticlinal wall

irregularly thickened, smooth to beaded. Periclinal wall thin, smooth.
Stomata randomly oriented, uniform distribution. Stomata 20–28 μm in length, 24–28 μm in width. Guard cells not sunken, granulate, small T-shaped thickening present. Outer stomatal ledge prominent, broad, dark-staining. S.I. 14.6. Stomatal arrangement staurocytic. Subsidiary cells 3–5, dark staining. Anticlinal wall irregularly thickened, smooth to beaded. Periclinal wall thick, smooth. Oil gland lid cells rare, isodiametric, slightly constricted at sinus, sinus undulate (2–3 waves), up to 10 scarcely modified to radially arranged surrounding cells, dimensions 32–48 μm in length, 40–48 μm in width.
Affinity: The cuticle parataxon has been assigned to the Myrtaceae due to the presence of oil gland lid cells of the type seen on modern members of the family.

Cuticle Parataxon No. DM 007
FIGS 19–20

Stomatiferous stem/shoot material was observed. Epidermal cells angular (usually hexagonal), arranged in longitudinal rows oriented parallel to the long axis of the shoot/stem. Cells 8–28 μm in length, 16–20 μm in width. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, smooth to granulate.
Stomata arranged in a uniseriate row near the shoot/stem margin, oriented perpendicular to the long axis of the shoot/stem. Stomata 20–24 μm in length, 8–12 μm in width. Guard cells not sunken. Outer stomatal ledge, prominent, broad, raised. Stomatal Arrangement none to paracytic. Subsidiary cells 0–2. Anticlinal wall, thin, smooth. Periclinal wall irregularly thickened, smooth to granulate.
Affinity: The cuticle parataxon has been assigned to *Gymnostoma* (Casuarinaceae) on the basis of predominently angular epidermal cells and the perpendicular orientation of stomates relative to the long axis of the shoot (Dilcher *et al.* 1990).

Cuticle Parataxon No. AWF 001
FIGS 21–22

Only the stomatiferous surface was observed. Epidermal cells angular to rounded. Cells between stomatal bands are generally arranged in longitudinal rows oriented parallel to the long axis of the leaf. Cells 28–116 μm in length, 16–48 μm in width. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, smooth to finely granulate.

Stomata arranged in short discontinuous uniseriate rows, oriented obliquely, transverse to parallel to the long axis of the leaf. Stomatal rows separated by 2–5 rows of rectangular epidermal cells, in narrow stomatal bands. Stomata 40–64 μm in length, 20–40 μm in width. Guard cells sunken. Stomatal ledge, prominent, narrow. Guard cell/subsidiary cell wall heavily cutinized, raised. Florin rings evident. Stomatal Arrangement cyclocytic. Subsidiary cells 4–5. Anticlinal wall irregularly thickened, smooth to beaded. Periclinal wall irregularly thickened, granulate to striate.
Affinity: The cuticle parataxon has been assigned to the Araucariaceae. The predominantly oblique orientation of the stomata and rounded epidermal cells suggests an affinity to *Agathis* (Cookson & Duigan 1951; Stockey & Taylor 1981; Hill & Bigwood 1985, 1987).

Cuticle Parataxon No. S3 004
FIGS 23–24

Only the stomatiferous surface was observed. Epidermal cells undulate (type 3). Cells 12–32 μm in length, 8–16 μm in width. Anticlinal wall thin, smooth. Periclinal wall thin, smooth.
Stomata randomly oriented, uniform distribution. Stomata 12–20 μm in length, 12–16 μm in width. Guard cells not sunken. Outer stomatal ledge, prominent, narrow, apiculate. Stomatal Arrangement staurocytic to cyclocytic. Subsidiary cells 3–5. Anticlinal wall, thin, smooth, radial walls may be poorly defined. Periclinal wall thin, smooth. Trichome bases common, over veins, poral, 7 radially arranged surrounding cells, cuticular thickening around pore. Hydathodes rare, over veins.
Affinity: The cuticle parataxon is placed in the Elaeocarpaceae due to the presence of hydathodes, an apiculate stomatal ledge and staurocytic stomatal arrangement.

Cuticle Parataxon No. S3 005
FIG 25

Only the stomatiferous surface was observed. Epidermal cells angular. Cells 10–33 μm in length, 5–23 μm in width. Anticlinal wall thin, smooth. Periclinal wall granulate.
Stomata randomly oriented, uniform distribution. Stomata 12–20 μm in length, 10–15 μm in width. Guard cells, not sunken, T-shaped thickening present. Outer stomatal ledge, prominent, narrow, apiculate. Stomatal Arrangement staurocytic. Subsidiary cells 2–5. Anticlinal wall, thin, smooth. Periclinal wall granulate. Hydathodes rare.
Affinity: The cuticle parataxon is placed in the Elaeocarpaceae due to the presence of hydathodes, an apiculate stomatal ledge and staurocytic stomatal arrangement.

Cuticle Parataxon No. LE 009
FIG. 26

Only the stomatiferous surface was observed. Epidermal cells rectangular, arranged in longitudinal rows oriented parallel to the long axis of the leaf. Cells 8-36 μm in length, 8-18 μm in width. Anticlinal wall buttressed. Periclinal wall thin, smooth. Stomata arranged in uniseriate rows, often short, occasionally merged, oriented parallel to the long axis of the leaf. Stomata 16–28 μm in length, 12-18 μm in width. Stomatal arrangement paratetracytic. Guard cells sunken. Stomatal ledge prominent, irregularly thickened. Subsidiary cells 4, heavily cutinized, lateral cells larger than polar cells. Polar cells may be shared. Anticlinal wall buttressed. Periclinal wall thick, smooth. Florin ring evident.
Affinity: Although very fragmentary the general cuticular morphology of specimens suggests an affinity to the Podocarpaceae.

Cuticle Parataxon No. SI 003
FIGS 27-28

Only the stomatal surface was observed. Epidermal cells sinuous (4), 64–104 μm in length, 56-80 μm in width. Anticlinal wall irregularly thickened, smooth to finely beaded to ridged. Periclinal wall granulate. Stomata randomly oriented, uniform distribution. Stomata 36–56 μm in length, 32–38 μm in width. Stomatal arrangement brachyparacytic. Guard cells sunken, broad polar rods, T-shaped thickening and poral thickening present. Outer stomatal ledge prominent, very broad. Subsidiary cells 2. Anticlinal wall beaded. Periclinal wall striate. Trichome bases common, 1-2 basal cells, heavily cutinized, raised anticlinal wall, 6–8 scarcely modified, radially arranged surrounding cells. Striations radiate outwards onto other epidermal cells.
Affinity: The cuticle parataxon is assigned to the Proteaceae due to presence of brachyparacytic stomata and multicellular trichome bases.

Cuticle Parataxon No. ALL 011
FIG. 29

Only stomatiferous surface observed. Epidermal cells angular to rounded, becoming elongate over veins. Cells 8-40 μm in length, 8–20 μm in width. Anticlinal wall thin, smooth. Periclinal wall thin, smooth. Stomata randomly oriented, uniform distribution within large areoles. Stomata 12–24 μm in length, 12-16 μm in width. S.I. 15.6 Stomatal arrangement actinocytic to staurocytic. Guard cells not to slightly sunken. Subsidiary cells 3-6, darker staining than epidermal cells. Anticlinal wall thin, smooth. Periclinal wall irregularly thickened, smooth to slightly granulate. Outer stomatal ledge prominent, narrow. Polar rods and some T-shaped thickening present on guard cells. Hydathodes rare, over veins, 28–40 μm in length, 16–20 μm in width.
Affinity: The cuticle parataxon is placed in the Elaeocarpaceae due to the presence of hydathodes, an apiculate stomatal ledge and staurocytic stomatal arrangement.

Floristic Comparison of Samples

The floras of each of the three samples possess a number of floristic features that distinguish them from one another. The flora of the upper seam is characterised by the dominance of the Proteaceae component and of one parataxon in particular, No. SI 001 which matches the cuticle of *Banksieaephyllum laeve* (Figs 17 & 18).

The flora of the lower lignite seam has a similar overall composition to that of the younger lignite seam but with a number of differences. These include: 1) the presence of parataxa No. S3 001 and No. AWF 001 both of which are absent from the other floras as well as being the sole contributors to the Myrtaceae and Araucariaceae components respectively. Both parataxa are potentially useful as stratigraphic indicators, at least locally within the depositional basin; 2) an increased abundance of the Podocarpaceae, Myrtaceae, Elaeocarpaceae and Casuarinaceae components which when combined, account for more than 25% of the flora. In no other lithotype do these components attain the same levels of significance either individually or combined.

The flora of the basal clay is easily distinguished from the other Sedan floras by the abundance of Lauraceae parataxa, of which some are related to the extant genera *Endiandra* and *Cryptocarya*, and the minor occurrence of Proteaceae parataxa.

Comparison of the floras of the three lithotypes reveals a distinct floristic difference between the two lignite seams and the basal lignitic clay seam. Both lignite floras are dominated by the Proteaceae with parataxon No. SI 001 the major contributor. The flora of the lignitic clay is very different with the Lauraceae dominating and the Proteaceae reduced to an insignificant level. It is also evident that there is a correlation between the lithotype and dominant floral type, i.e the Proteaceae are associated with the lignite whereas the Lauraceae are associated with the clay.

Examination of modern sedimentary environments has shown that quite different leaf-floras (and by inference, different cuticle floras) are found in separate sedimentary environments (Burnham 1989; Taggart 1988). Within the same stratigraphic sequence these changes in environment may be due to either hydrological succession or climatic changes which subsequently induce changes in the plant community (Luly *et al.* 1980). The correlation between the two lithotypes and the two dispersed cuticle floras therefore indicates that both floras are the product of different sedimentary environments (Taggart 1988); the Lauraceae-dominated lignitic clay and the Proteaceae-dominated lignite. The lignitic clay is likely to have been deposited under open-water conditions, with mainly allochthonous, potentially extra-local (Lauraceae-dominated flora), plant remains, whereas the lignite represents swamp conditions with mainly local deposition (i.e. Proteaceae-dominated flora).

Comparison with Other Australian Tertiary Deposits

The dispersed cuticle floras of the Sedan deposit include a number of parataxa which are known to occur in other Australian Tertiary deposits. The presence of the very distinctive cuticle of *Banksieaephyllum laeve* in the Sedan lignites, i.e. *Banksieaephyllum* aff. *B. laeve*, would appear to be of some biostratigraphic significance. *B. laeve* has to date only been reported from the Yallourn (Oligocene) and Morwell (Miocene) coal seams of the Latrobe Valley and the Inkerman-Balaklava lignites of the Bowmans deposit, 100 km north of Adelaide (Blackburn 1985). The latter deposit is located a short distance south of the Sedan deposit in the adjoining St Vincent Basin. Although the stratigraphic evidence is limited, it is consistent, with *B. laeve* only being reported from Oligocene-Miocene coals and as one of these coal deposits lies is close vicinity to the Sedan deposit then a younger age could be inferred.

Conversely, based on palynological and micropalaeontological evidence, the presence of *B. laeve* cuticle in the Sedan lignite could imply the leaf fossil has a longer stratigraphic range than previously reported, i.e Late Eocene-Miocene.

The basal lignitic clay is dominated by the Lauraceae, which is of no stratigraphic significance as the family was well represented throughout the Australian Eocene. A comparison of Eocene Lauraceae cuticle types from a number of localities, including Anglesea (Rowett & Christophel 1990) and Nerriga (Hill 1986) has shown that both of the genera identified in this lithotype, i.e. *Cryptocarya* and *Endiandra*, were well represented in terms of species and abundance throughout the period. It should be noted that the lauraceous megafossils of the Nerriga locality were assigned to the form genus *Laurophyllum* by Hill, but affinities to *Endiandra* and *Cryptocarya* were also indicated for a number of these leaf types. It must also be mentioned that the two genera are the major contributors to the modern Australian Lauraceae.

However, the presence of the Lauraceae parataxon No. AA 006 may prove to be an important stratigraphic indicator, based on the author's unpublished information. This parataxon appears to have a restricted distribution, being only recorded in Middle Eocene deposits and reaching maximum abundance in the Upper Middle Eocene. It has not at this present time been identified in Late Eocene or younger sediments.

In conclusion, it is evident from the analysis of the dispersed cuticles of the Sedan coal sequence that 1) two separate dispersed cuticle floras are recognised, i.e. the Lauraceae-dominated flora of the basal lignitic clay and the Proteaceae-dominated flora of the younger lignites; 2) the change in lithotype and flora recognised between the basal clay and lignites may be climatically induced; 3) the key cuticle type *Banksieaephyllum* aff. *B. laeve* recorded at Sedan occurs in younger lignite sequences in the Latrobe Valley (Victoria) and Bowmans deposit (South Australia) suggesting either that the Sedan lignites are younger than indicated by both the micropalaeontology and palynology or that the stratigraphic range (Oligocene-Miocene) of the cuticle type is longer than suggested by the present records.

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